Release of *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) on the Hemlock Woolly Adelgid, *Adelges tsugae* (Homoptera: Adelgidae) in NJ

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***P. tsugae* on hemlock needle**
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INTRODUCTION

In the spring of 1997, under a cooperative agreement with the United States Forest Service (USFS), the New Jersey Department of Agriculture's (NJDA) Phillip Alampi Beneficial Insect Laboratory (PABIL) received 100 *Pseudoscymnus tsugae* (Coleoptera: Coccinellidae) from Dr. Mark McClure and Dr. Carole Cheah of the Connecticut Agricultural Experiment Station (CAES) to serve as a back up to their colony. One of the goals of the PABIL was to try to further develop and refine the rearing procedures for *P. tsugae*. If sufficient numbers of the beetle were produced, they would be released in NJ. Beginning in 1998 and continuing through 2001, a total of 221,000 *P. tsugae* has been released into NJ forests. A little over half of the production at PABIL has been shipped to other northeastern states infested with the HWA. Between 1998 and 2001 a total of 171,500 *P. tsugae* have been shipped for release in nine other states.

Overview

The hemlock woolly adelgid (HWA) (*Adelges tsugae* Annand) is a catastrophic introduced pest of hemlock trees in the eastern United States. The adelgid feeds at the bases of needles, desiccating them, causing needle loss and preventing the trees from producing new growth. After a forest stand has become heavily infested with the HWA, tree mortality may develop in as little as three years. Some trees survive longer but their vigor is greatly reduced. In an effort to save as many hemlock stands in NJ as possible, the NJDA in cooperation with the USDA-Forest Service and the Connecticut Agricultural Experiment Station has initiated a biological control program using the exotic ladybug *P. tsugae*.

P. tsugae is from Japan as is the hemlock woolly adelgid. This tiny beetle has a very narrow host range and feeds exclusively on adelgids, primarily the HWA. It has been reared and has reproduced on other adelgid species in the laboratory but not to the same extent as on HWA. The life cycle of the beetle is synchronous with that of the HWA, so much so that the beetle enters summer dormancy when the HWA does and only becomes active again when the HWA is active.

HWA is a common, but insignificant insect on ornamental and forest hemlock and spruce in Japan and China. It does not attain high densities on hemlock in Japan except for trees growing on very poor sites. There is no significant injury to the Japanese hemlocks most probably due to host resistance and the presence of native predators such as *P. tsugae* that regulate HWA populations.

The first infestations of North American hemlocks were in the 1920's in British Columbia and by the 1950's the HWA was discovered on the east coast. Both of these infestations are believed to be accidental introductions from Japan. The western North American species of hemlock (*Tsuga mertensiana*, mountain hemlock and *T. heterophylla*, western hemlock) are resistant to the HWA but the insect can be found on stressed trees. The eastern North American hemlocks (*T. canadensis*, eastern hemlock and *T. caroliniana*, Carolina hemlock) have no such resistance.

Eastern hemlocks are the successional climax trees in northern NJ forests. Hemlock is not a valuable timber tree but the wood is used for barns, sheds, pulpwood, and landscaping. There are 274 cultivars of eastern hemlock, which makes it very important to the nursery industry and in landscapes. Hemlock is ecologically important providing cover for deer, turkey, ruffed grouse, and others. About 90 species of birds use hemlock as a nesting site, roost site or winter shelter. Northern goshawk, solitary vireo, and the black-throated warbler require habitats provided by a hemlock forest and would be stressed should the hemlock stands be reduced for any reason. Hemlock is also an important component of some of the more popular recreational areas in NJ. Due to the dense canopy, hemlock stands are cooler in summer providing a much-needed respite from the heat for those who visit the stands.

In NJ, virtually all of the forest stands have some level of HWA infestation. In the 2001 fall survey, results of 156 monitored stands showed that 68% had an easily detectable HWA population and that 42% of those stands were heavily infested. In these heavily infested stands, over half (57%) were also heavily infested during the last survey in 1997, while 32% of the stands have increased to a heavy infestation level since the 1997 survey. The healthiest stands were in northern Passaic and Sussex Counties, but the HWA is starting to increase in this area and they will not remain healthy for long unless a biological control effort is undertaken**.** In the NJDA Permanent Study Plots, the

mortality due to the HWA in the heavily infested stands ranges from 38% to 96%**.** It is not improving. The trend is for the mortality to increase in stands that are heavily infested, especially those that have been heavily infested for the second time.

HWA populations are virtually unmanageable in hemlock forests using traditional control measures. Chemical insecticides are impractical to apply in the forest due to the inaccessibility of most stands, poor coverage for aerial spraying and/or excessive cost. In addition, many hemlock stands border streams and cannot be sprayed because of potential drift into the water. In heavily infested stands, the HWA multiplies quickly and can attain high densities during the first few years of an infestation. The trees are defoliated, although not completely, which causes the adelgid population to drop due to the reduced vigor and reduced new growth on the trees. The trees recover to some degree but never completely and the HWA population rapidly builds when there is abundant new growth on the trees. This leads to a cycle of decline and recovery but the trend in the cycle is ever downward resulting in tree death. Some trees survive for a number of years but only with a sparse crown at the very top of the tree. The only hope for the trees in the forest is biological control.

Biological Control

In 1992, Dr. Mark McClure of the CAES initiated a trip to Japan to attempt to find and collect some HWA predators. He discovered two: an Oribatid mite *Diapterobates humeralis* and a Coccinellid, *P. tsugae*. The mite feeds on the white, woolly, waxy secretions of the adelgid and was found to be already present in North America, but not all that effective as a control. *P. tsugae* was found to be an effective control and the USDA granted a permit for release in 1995. Although the data from these releases has not been published as yet, the results are very encouraging with the beetles having reduced the HWA population between 40% to 88% at sites in Connecticut (M. McClure, personal communication). Dr. Mike Montgomery of the USDA-FS is working with two *Scymnus* spp. from China but those species are still under evaluation and Dr. Scott Salom is working with a Derodontid beetle, *Laricobius nigrinus*.

The Case for Biological Control

P. tsugae is one of the last best hopes for the hemlocks in NJ. Evidence from Dr. McClure's work indicates that the beetles do not do very well in stands where the trees have been stressed. Therefore, to maximize their effectiveness, the beetles should be released into hemlock stands that are still vigorous. Some of the natural areas in NJ have substantial hemlock forests within them, especially those at Wawayanda. They all are infested to some degree with HWA and it is just a matter of time before the adelgid population increases to the point that the trees start to decline. By using biological control in those stands we will attempt to set up a balance between the HWA and *P. tsugae* where the adelgid is not eliminated from the stand but where the HWA population levels will be reduced to a level that the trees can tolerate. If this balance is established, the beetle and HWA populations will fluctuate in a classic predator-prey relationship but the carrying capacity for the HWA will be reduced. The timing of the releases is critical. If nothing is done, it is very likely that there will be high mortality in the remaining hemlock stands in NJ and the natural hemlock stands will be far different than they are now.

The risk of releasing *P. tsugae* is extremely small. It does not feed on anything but adelgids and is very host specific to the HWA. No native coccinellid, or other predator for that matter, occupies the same niche that *P. tsugae* does. It would not be displacing any of our native coccinellids and it would most likely have a negligible impact on other adelgid species.

Figure 1. *Pseudoscymnus tsugae* recovery

Photo by L. Bronhard

MATERIALS AND METHODS

In 1998, five data sites were established, with one of them, at Wawayanda State Park, set up for a joint experiment with Dr. McClure using his experimental design. The Wawayanda site has been dropped due to a dearth of HWA at the site and too many zeros in the data, which leads to no conclusions. The other four sites were established in different NJ forests using a similar but modified procedure. One of the sites was to be used as a control. All the sites were scouted beforehand as to their suitability. Dr. McClure's procedure involved setting up transects in four compass directions as close to the cardinal points as possible, with four plots placed 50 m apart along each transect. Each plot consisted of four trees marked with metal tags. Using a method developed by Dr. Tim Tigner in Virginia, the following information was gathered from each tree:

Tree # _____ Crown Class: D = dominant CD = co-dominant I = intermediate S = suppressed
DBH:_____inches = diameter at breast height **Crown Ratio:_____**%
% Live Branches_____% **New Foliage:** >50% of branches; < 50% of branches; absent
Foliage Color: dark green above; not as green above **Overall Appearance:** healthy; good; fair; poor; dead
Crown Condition: full; thin; some dieback; heavy dieback; dead
HWA present on: <25%; 25-50%, 50-75%, >75% of foliage
Prior HWA Infestation: HWA remnants; branch dieback; no evidence
HWA Egg Mass Counts on 10 cm. of the branch tip from the terminal end. All lateral tips were counted. This differs from the method of Dr. McClure in which 30 total cm of new growth were counted alternating left and right from the tip. In some of the NJ sites there is very little new growth to count so all adelgids on the twigs were counted.
Spring: Branch 1_____; Branch 2_____; Branch 3_____;
Fall: Branch 1_____; Branch 2_____; Branch 3_____;

Counts of the sistens (overwintering) stage of the HWA were made in March and in October the first season and then only in October the following seasons.

The three NJDA data collection sites were set up in Stokes State Forest, a lightly infested site with healthy trees; Kittatinny Valley State Park, a heavily infested site with healthy trees; and Jenny Jump State Forest, a heavily infested site with unhealthy trees. Abraham Hewitt State Forest served as the control. The sites varied from Dr. McClure's plot design in that five groups of five trees were set up 50 m apart with one group centrally located and the others situated approximately 50 m from it as illustrated below.

0 0

0

0 0

Trees were selected that had HWA populations on them and instead of sampling 30 cm as in Dr. McClure's procedure, a 10 cm section was measured back from the tip and all the adelgids including the ones on the laterals were counted.

Also, the percent new growth was determined using the same tips that were sampled for the counts of the sistens stage. The branches were not marked but an average number of the HWA in the stand was determined. The number of HWA and the percent new growth will be recorded every year to get an inference of the effect of the *P. tsugae* on the HWA population. A total of 10,000 beetles were released in each of the three sites, 2,000 *P. tsugae* per subplot with 500 *P. tsugae* released on four of the five trees in each of the subplots.

In 1999, another data intensive plot was set up at Allamuchy State Park using the protocols developed by the USFS and Dr. McClure. The site was set up very much like the Wawayanda site with the difference being that the subplots were 100 m apart instead of 50 m. A change was made in the data collection method by the USFS in order to simplify things for cooperators. As with the Wawayanda site, the data is forwarded to the USFS.

Monitoring for the presence of *P. tsugae* was conducted monthly if possible. Surveys were conducted at all the data sites as well as all other release sites within the state. Each site was surveyed for 2.5 hours or until a *P. tsugae* was found. A one meter square beating sheet was placed beneath several branches and the branches were struck ten times with a plastic whiffle ball bat. Any life stages of *P. tsugae* on the sheet were recorded.

A new survey technique was employed this year in an effort to recover more *P. tsugae*. Dr. Mark McClure has established that the beetles over winter on the tree and is of the opinion that the beetles are higher up in the canopy in the years following release (Personal Communication). In order to test Dr. McClure's theory, the PABIL rented a bucket truck from Geils Tree Service in Ringoes, New Jersey. The truck was a 1996 International 4900 with a 60-foot boom. A single release of 2,500 beetles was made on an infested tree near the Shotwell campground area in Stokes State Forest on 5/3/01. Trees were sampled using a one meter square beating sheet and a whiffle ball bat used to strike the branches, every meter on the tree. Only trees along the road were sampled due to the size limitations of the bucket truck. Height was measured using a weight attached to a string that was marked off in one-meter increments.

RESULTS AND DISCUSSION

The PABIL continues to provide sufficient numbers of *P. tsugae* for release both in NJ and in other states. A total of 30,500 *P. tsugae* were released into 7 sites in 2001. Table 1 summarizes the production levels and releases of *P. tsugae* from 1997 through 2001.

Table 1. *Pseudoscymnus tsugae* Production and Releases 1997 - 2001

Year	Total No. Produced	No. Released in New Jersey	No. of Sites	No. Shipped to Other States
1997*	600	0	0	0
1998	90,000	75,500	15	5,000
1999	140,000	65,000	13	70,000
2000	120,000	50,000	13	57,700
2001	74,800	30,500	7	38,800
Total	**425,400**	**221,000**	**48**	**171,500**

*****From a starter colony of 100 adult beetles received in May 1997

The recovery of two adults this year (both at the Swartswood SP site) has demonstrated that *P. tsugae* continues to successfully over winter in New Jersey (Table 2). This is the third consecutive year that recoveries have been made, although the number of recoveries has been decreasing each year. The fact that living, reachable lower branches are becoming fewer and fewer on the release trees is probably a major reason for the decreasing numbers of beetles found. The beetles have dispersed to the higher branches, which are unreachable by the survey personnel.

Larvae were recovered again in 2001, but from two different sites than in 2000. An overwintering larval recovery was made at the Swartswood SP boat launch site and a same season recovery was made at the Walpack WMA site on Mountain Rd. South. This is significant because it confirms that the beetles are reproducing in the field in the year after release. The larvae are difficult to find because they hang on tightly to the branches. Even if you manage to dislodge one, they are extremely difficult to find because they cling to the needles and other debris on the beating sheet, so developing a searching image for them takes some time**.** Also, the lack of live lower branches as explained above affects recovery of larvae.

Table 2. *Pseudoscymnus tsugae* Releases and Recoveries 1998-2001

Release Year	County	Location	Site Totals	*P. tsugae* Recovery 1999	2000	2001
1998	Sussex	Wawayanda State Park	10,000	Adult		
1998	Sussex	Kittatinny Valley State Park	10,000	Adult		
1998	Sussex	Stokes State Forest	10,000	Adult		
1998	Warren	Jenny Jump State Forest	10,000	Adult		
1998	Sussex	Johnson Lake Plot	3,000		Adult	
1998	Sussex	Sparta Glen	6,000			
1998	Morris	Schooley's Mountain Plot	3,000			
1998	Morris	Lake Valhalla Plot	5,000			
1998	Warren	Shades of Death Plot	2,500			
1998	Warren	Worthington State Forest	5,000	Adult	Adult	
1998	Mercer	Washington Crossing State Park	1,500			
1998	Mercer	Princeton Battlefield State Park	1,500			
1998	Monmouth	Walnridge Farm Plot	3,000			
1998	Monmouth	Freer Nature Preserve	4,500	Adult		
1998	Monmouth	Deep Cut Park	500			
1998	**Total**		**75,500**			
1999	Hunterdon	Ken Lockwood Gorge W.M.A.	5000			
1999	Hunterdon	Pine Hill Section, S. Branch Res.	3500			
1999	Morris	Hacklebarney State Park	5000			
1999	Morris	Rockaway River W.M.A. Jefferson Twp.	5000			
1999	Passaic	Clinton Reservoir, South of PSP	4500			
1999	Sussex	Allamuchy State Park	10000			
1999	Sussex	Glenwood Mt. AT Site	5000			
1999	Sussex	High Point P.S.P.	5000			
1999	Sussex	High Point SP--AT shelter	5000			
1999	Sussex	Sparta Mt. W.M.A. Ogdensburg	2500			
1999	Sussex	Tillman's Ravine P.S.P	5000		Adult	
1999	Sussex	Wawayanda Hemlock Ravine	5000			
1999	Warren	Dunnfield Creek, Worthington State Forest	5000			
1999	**Total**		**65000**			
2000	Hunterdon	Stanton Station Park Site	2500		Larval	
2000	Hunterdon	Westcott Preserve	2500			
2000	Hunterdon	Wickecheoke Creek Reserve	5000		Larval	
2000	Passaic	Newark Watershed - Cedar Pond	2500			
2000	Pike, PA	DWGNRA - Adams Creek	7500			
2000	Sussex	Flatbrook WMA	5000			
2000	Sussex	Swartswood State Park	5000			2 Adults 1 Larval
2000	Sussex	Tillman's Ravine	2500			
2000	Sussex	Wawayanda Hemlock Ravine Natural Area	2500			
2000	Sussex	Wawayanda Swamp Natural Area	2500			
2000	Sussex	White Lake WMA	2500			
2000	Sussex	Walpack WMA - Mountain Rd.	5000			Larval
2000	Sussex	Stokes State Forest - Stoney Lake	5000			
2000	Sussex	DWGNRA – Van Campen's Brook	7500			
2000	**Total**		**50000**			

Release Year	County	Location	Site Totals	*P. tsugae* Recovery 1999	2000	2001
2001	Passaic	Wawayanda SP – Clinton Rd.	5000			**Adult**
2001	Sussex	Walpack WMA – Mountain Rd. South	5000			Adult Larval
2001	Sussex	Stokes SF – Rd. to Shotwell Campground	5000			Adult
2001	Sussex	DWGNRA – Van Campen's Brook	5000			
2001	Sussex	Stokes SF – Lake Ocquittunk Campground	5000			Adult
2001	Sussex	Stokes SF – Woods Rd. & Shay Rd.	2500			Adult
2001	Sussex	Swartswood SP – Boat Trailer Launch	3000			Adult
2001	**Total**		**30,500**			

By looking at the HWA population counts and the percentage of new growth, it may be possible to measure any impact that *P. tsugae* is having on the HWA. Table 3 shows the sistens (over wintering) population counts over the course of the project along with the percentage of new growth.

Table 3. Average Sistens Population Counts/10 cm and Percent New Growth 1998 - 2001

Average Sistens Population Counts/10 cm

Site	1998* Spring	1998 Fall	1999 Fall	2000 Fall	2001 Fall
Jenny Jump SF	73.5	38.8	13.6	7.8	26.7
Kittatinny Valley SP	55.9	44.2	4.3	0.4	10.4
Stokes SF	41.1	140.9	7.6	2.6	17.9
Abraham Hewitt SF (control)	34.3	52.0	1.4	1.1	23.1

Percent New Growth 1998-2001

Site	1998 % New Growth	1999 % New Growth	2000 % New Growth	2001 % New Growth
Jenny Jump SF	27.1%	17.4%	10.7%	27.0%
Kittatinny Valley SP	46.8%	1.1%	10.4%	48.8%
Stokes SF	63.3%	4.0%	13.7%	66.4%
Abraham Hewitt SF (control)	26.5%	1.8%	26.6%	72.3%

*represents fall 1997

We did not expect much, if any, impact on the HWA population in 1998 because it was the first year of release. In 1999, the sistens population declined at all of the sites, including the control at Abraham Hewitt State Forest. The populations declined at all sites again in 2000**,** but in 2001 they all experienced an increase. This effect can be attributed to the amount of new growth that occurred during the 2001 growing season at all the sites. The site conditions can have a large effect on the sistens population in that the amount of new growth is conducive to a greater population. The increased new growth provides more suitable feeding places for the HWA nymphs, which resulted in a population increase. The percent new growth is the key to the data here. When new growth declines, the hemlock woolly adelgid population goes down and it has nothing to do with the *P. tsugae* population at this time.

Very little then, can be said as yet about the impacts of the *P. tsugae* because they simply have not had time to reproduce to population levels that could control the hemlock woolly adelgid. The population levels of the hemlock woolly adelgid also affect their reproduction. If there is plenty of new growth there will be plenty of adelgid and vice versa. Logically, the beetles will be difficult to recover in an area where the population has crashed. Also, when there is dieback on a tree due to the hemlock woolly adelgid, the lower branches go first which leave us with less to sample in succeeding seasons since the sampling is done from branches accessible from the ground.

In areas that are newly infested with the HWA, the HWA population may increase rather than decrease when *P. tsugae* is released. An insufficient number of beetles are released to have any dramatic impact on the forest. It is too soon to determine the impact the releases may have on the hemlock woolly adelgid. The larger concern is whether sufficient releases can be made in time to produce enough *P. tsugae* to reduce the HWA population before

the trees are devastated beyond recovery.

Sampling for *P. tsugae*

Crown ratings are used to evaluate the health of the trees in the sturdy plots (Table 4). Overall, the general health of the trees is declining. Releasing 10,000 beetles into the middle of a forest sounds like a lot but when one considers the number of trees, the number of beetles released would be hard pressed to have an impact on an individual tree. The key evaluation data are the crown ratio, percent new growth and the overall appearance.

With some minor exceptions, all three categories have gotten worse since the release of the beetles. This is to be expected since the number of beetles released is insufficient to show an immediate impact in the forest. The crown ratio has stayed relatively the same, which is a good sign because the trees may still recover. The goal is to release the beetles in strategic areas in order for the beetles to reproduce on their own and eventually the hope is that they will reach population levels that will moderate the hemlock woolly adelgid population in time.

***P. tsugae* Behavior**

The behavior of *P. tsugae* after they have been released on a tree is to disperse upwards towards the canopy. As previously mentioned, Dr. Mark McClure has established that the beetles over winter on the tree and is of the opinion that the beetles are higher up in the canopy in the years following release (Personal Communication). Hodek (1973) has reported that Coccinellids readily disperse and this may be true of *Pseudoscymnus*. This could be one of the reasons that recovery numbers of the beetles have been lower than expected for the number of beetles released (see Table 2). To try and determine if this is indeed the behavior of these beetles, surveys of certain release trees were conducted using a bucket truck. Following the release of 2,500 beetles on a tree at a site in Stokes State Forest on 5/3/01, a ground survey of the area was made on 6/8/01 with the recovery of 6 adult beetles. A second survey was performed on 6/13/01 with the aid of the bucket truck. Table 5 shows the number of beetles recovered at the various heights of the tree.

Table 5. Distribution of *P. tsugae* per meter.

	# *P. tsugae* per meter		
Height (m)	**Adjacent tree**	**Release Tree**	**Adjacent Tree**
15	**0**	**0**	**-**
14	**0**	**0**	**0**
13	**0**	**-**	**0**
12	**0**	**3**	**0**
11	**-**	**-**	**0**
10	**0**	**2**	**0**
9	**0**	**6**	**2**
8	**0**	**7**	**-**
7	**0**	**3**	**-**
6	**-**	**-**	**0**
5	**0**	**4**	**0**
4	**0**	**0**	**1**
3	**0**	**0**	**0**
2	**0**	**0**	**0**
1	**0**	**0**	**0**

The results are quite conclusive. No beetles were recovered at heights less than three meters on any of the trees. The majority of the beetles were recovered at nine and at eight meters. On one adjacent tree beetles were recovered at four and at nine meters. Ground surveys at one and two meters recovered no beetles. In past seasons, no further

recoveries would have been made from this site. The data indicates that the *P. tsugae* do move up the tree as the season progresses and even if no recoveries are made at a release site at ground level, the beetles are probably still there, but up in the canopy where they normally cannot be sampled.

Observations in the laboratory also bear this out with the beetles moving up onto the top of the Plexiglas cages.

Surveys using the bucket truck were made for over wintering beetles at the following year 2000 release sites: Flatbrook WMA, Stony Lake in Stokes State Forest, and at Swartswood State Park. The beetles were only recovered at Swartswood State Park but the recovery there was significant for two reasons: 1) the adult beetles were recovered about 10 m high in the tree and 2) a larva was recovered there as well. The recovery of the adults shows that the beetles do move up the tree and that they are there in succeeding seasons. The larval recovery confirms evidence that the beetles are reproducing in the field in the seasons following release.

Evidently, the beetles are still there after they have been released but are difficult to find because of the lack of food material on the lower branches and the fact that they disperse to the upper canopy. Therefore, when field surveys are made from the ground and no beetles are recovered, it does not mean that the beetles are not there, but that the beetles are in the upper canopy where they cannot be sampled by ground crews.

As the population of *P. tsugae* increases with that of the hemlock woolly adelgid, they should become easier to find as was the case with other species of coccinellids released by the Phillip Alampi Beneficial Insect Laboratory.

The impact of this beetle will be difficult to assess long term if just the population levels of both the beetle and the adelgid are monitored. There may be no numerical response that can be quantified but it will be the absence of the pest and the presence of new growth at the same time that may determine whether the program is successful. It will be the absence of the pest rather than the presence of the beetle that will signal the effectiveness of the program.

Time concerns

The long-term success of the program depends on the ability of the beetle to control the HWA or at least suppress it sufficiently so that the trees are able to recover. The HWA has moved into all of the remaining uninfested stands in NJ, which can trigger a 4-year decline in the health of the trees. What is unknown is whether sufficient *P. tsugae* will be released in time to control the HWA. In the past when PABIL staff has released coccinellids, there was a minimum of a three-year lag before any beetles were recovered. *P. tsugae* have been recovered in less time but it is too soon to tell. There are no other cost effective controls available to protect natural hemlock stands at this time other than biological control.

2002 Plans

In 2002, the PABIL intends to decrease the number of release sites over 2001. The goal is to release a maximum number of beetles per site in high value public forested areas in northern NJ in an attempt to boost their reproduction. Eventually the goal is to establish the beetles throughout the state to protect as much of the forested area as possible. The releases will be made according to a priority list as follows:

1. State and Federal lands, including natural lands that are located in areas in close proximity to other stands where the beetles can redistribute themselves readily.

2. County and municipal lands that are located in areas in close proximity to other stands where the beetles can redistribute themselves readily.

Sites where no releases will be made in 2002.

- Private forested lands.
- Commercial Nurseries. Pesticides can be used in this situation.
- Commercial landscapes. Pesticides can be used in this situation.
- Homeowner landscapes. Pesticides can be used in this situation.

Reasoning: 1) Insufficient number of beetles available, 2) Areas may not be as conducive to beetle establishment because of pesticide use or, 3) The areas are not strategically located in the problem areas of the state, 4) Additional evaluations of the beetles effectiveness are needed; we must make sure that the beetles are effective before expanding it to include the sites above, 5) the USFS wants us to keep the number of release sites to a minimum until we can be sure that the *P. tsugae* are effective, 6) pesticides can be used to protect tree but not in natural stands.

The area of the state where the majority of the natural hemlock forest is located is in the northern fifth of the state above Interstate 80. That is where the HWA poses the greatest threat to the resource. It is also the area where the HWA is hardest to control because of the inaccessibility of the terrain. Unlike homeowners and commercial landscapers who can use pesticides to effectively control the HWA in the landscape, foresters cannot use pesticides in the natural forest. The cost of insecticide treatment is prohibitive, its effectiveness is minimal and there could be negative ecological effects**.** The USFS and NJ Forest Service have provided funds to help keep the biological control program going and the priority is to save the resource in Northern NJ where the problem is most acute. Once the beetles are well established in the natural stands an effort will be made to protect the trees in the nursery and the landscape.

CONCLUSION

The first four years of the *P. tsugae* program have been successful in that the beetles have become established in our state as evidenced by the recoveries of adults and/or larvae at 12 sites. It is probable that *P. tsugae* is established at more sites, but the mortality of the lower branches in many sites limits the search area survey personnel are able to reach when conducting surveys. Also, the behavior of the beetles to move up into the canopy of the tree following release makes recovery of the beetles difficult. A total of 30,500 beetles were released in NJ forests in 2001, which brings the total to 221,000 beetles that have been released in NJ, which is more beetles than have been released into any other state**.** Releases will be made into some new sites in 2002 concentrating on the remaining hemlock forest that is still healthy. It is too early to tell what the impact of the *P. tsugae* releases will be and the crown conditions have declined in all of the stands despite the releases.

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